After obtaining these results, the Council went on to ascertain the OOBE level at which a co-location standard could be established. At an OOBE level of –85 dBW/MHz, four of the nine tested receivers lost tracking of GPS satellites at distances as far out as seven meters from the noise source. While this is an improvement over the situation from –70 dBW/MHz, it is clearly inadequate (as all of the tested receiver types are in widespread use today, and will remain so for the foreseeable future). Only after the OOBE level was dropped to –100 dBW/MHz in the GPS band was it the case that all of the tested receivers maintained tracking of all satellites at distances of one meter from the noise source.

Only one of the tests (at the –85 dBW/MHz level) evaluated the impact of multiple (in this case, two) noise sources on the GPS receivers. When two noise sources were used to assess the interference effects on the five tested receivers, there was a significant impact on the number of satellites tracked in each case. Tests were conducted at distances of four meters and three meters, respectively. At four meters, the number of satellites lost when a second noise source was turned on ranged from one of eight (12.5%) in the mildest case, to six of six (100%) in the most severe. As the distance was decreased to three meters, the number of satellites lost when a

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- Handheld units are affected at 9 meters. The general public is beginning to rely on GPS as a safety tool, as mentioned in an article in Sports Trend magazine (p. 75), May 1999 entitled "Safety Feature Igniting GPS Sales." In the Key Trends in GPS box, the author states: "Consumers view GPS as a safety tool, a major selling feature." The kind of interference caused by the –70 dBW/MHz OOBE will ultimately cause a deterioration in the availability of the GPS signal and will result in a loss of confidence by the public in GPS.
- General Avionics equipment is severely affected, and could not operate if the OOBE from a communications device were operating in the same cockpit of a private airplane. This is true for both in-dash mounted equipment and handhelds, as are commonly available today.

second noise source was turned on ranged from three of seven in the mildest case, to six of six and five of five (each 100%) in the two most severe cases. *See* Attachment 1 at page 11.

In short, based on the tests conducted by the Council, aggregate OOBE levels not exceeding –100 dBW/MHz in the GPS band would appear to provide the requisite protection of GPS receivers. OOBE levels of –70 dBW/MHz, for any emitter other than MSS METs operating in the 1-3 GHz band (which are in a special circumstances) clearly and objectively do not adequately protest GPS.

C. Even The Post-2005 OOBE Limits That Have Been Proposed In The *NPRM* Are Insufficient, By Themselves, To Protect All GPS Operational Situations.

In the NPRM, the Commission proposes that, as of January 1, 2005, the OOBE limits of -70 dBW/MHz on wideband and –80 dBW/MHz on narrowband emissions in the 1559-1605 MHz band would also apply to MSS terminals transmitting on frequencies between 1610 and 1660.5 MHz that are placed in service *before* 2002.[23] These proposals for "final" or permanent OOBE limits are based on recommendations made by the NTIA in a September 1997 petition for rule making that is now part of this proceeding.[24]

The Commission requests comment on the assumptions underlying NTIA's recommendations.[25] At the outset, the Council notes that the fact that the proposed limits are based on the NTIA recommendations is directly responsible for the principal shortcoming of the

[23] *Id.*

[24] *See NPRM,* FCC 99-37, slip op. at 26 (¶ 61).

[25] *See id.* at 27 (¶ 62).

NPRM. The reason for this, as noted above, is that the NTIA petition was limited exclusively on "approach, landing, and surface operation" of aircraft, and thus does not cover the myriad other aviation, land, and marine situations where GPS is in current use in public safety and critical navigation situations.[26]

The NTIA recommendation was intended to protect GPS receivers in a one specific scenario – as such, the proposed standards cannot be presumed, without independent study and confirmation to provide adequate protection in scenarios where the assumptions are inapplicable.[27] In the specific case for which the NTIA proposal was developed, the victim GPS antenna was located on the top of an airplane fuselage and pointed up toward the satellite, and the aircraft fuselage shielded the antenna from any single interfering MSS MET located on the ground as the plane passed overhead.[28] Moreover, the MSS user – a single, ground-based omnidirectional transmitter – was assumed to be at least 30 meters (100 feet) away from the GPS antenna at the time the aircraft is most vulnerable and sensitive to interference.[29]

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[26] NTIA Petition For Rule Making (Page 1 of enclosure).

[27] The Council, for example, has questioned the suitability of the proposed -70 dBW/MHz emission limit to protect GPS from emissions from such distant interfering sources as RF lighting devises that are contemplated for operation in the 2.4 GHz band. *See* Reply Comments of the U.S. GPS Industry Council on RF Lighting Devices, ET Docket No. 98-42, at 4 (filed August 25, 1998).

[28] *See* "Assessment of Radio Frequency Interference Relevant to the GNSS," Document No. RTCA/DO-235 (January 27,1997).

None of the distance, shielding, and MSS earth terminal assumptions apply in any of a number of critical land and marine safety-related applications – and not even in other aeronautical scenarios – where mobile GPS receivers and mobile MSS transceivers can be expected to interact. Further, there is no proof whatsoever that the NTIA criteria are effective in situations where all three of the conditions above do not exist. Indeed, GPS receivers are used in ambulances, police cars, fire engines, for harbor-harbor entrance navigation, search and rescue, and docking of large marine vessels, such as oil tankers and high-speed ferries. These applications share the public safety mandate that applies to aircraft operations – the GNSS signals must be continuously available without disruption due to interference. Unlike GPS receivers located on landing aircraft, however, these receivers are likely to be operated in close proximity to or even on a co-location basis with MSS mobile earth terminals. In other words, none of the three conditions under which the OOBE levels proposed by NTIA and the Commission would "protect" GPS are present.

In fact, the adoption of the proposed emissions limits of the *NPRM* would result in the disruption of all GPS applications, whether land or air based, and whether safety-related or not. This is so because GPS satellites broadcast a very low power, one-way, signal. The received signal power only supports a data rate of 50 bits per second. The GPS signal comes from satellites that are 11,000 miles away providing very lower power flux densities at the

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[29] *See id.* A separation of 30 meters results in an attenuation of the MSS signal due to path loss of 66.1 dB. The airframe blocking results in a differential antenna gain of at least 5.5 dB. It is also noted that the –70 dB assumption was based on continuous tracking, not reacquisition, which can occur in urban canyons and crowded harbors. In these cases, the necessity for reacquisition is triggered by the physical topology.

earth's surface. This means that the GPS signals are inherently susceptible to OOBE generated locally. This problem is aggravated by the mobile nature of the use of the proposed system.

Moreover, the basic GPS system architecture has been unchanged since its conception in 1973. It is a characteristic of the GPS system itself, and no retrofit of the receivers, itself impractical, could enable continuous availability in the proposed interference environments.[30]

In sum, emission levels proposed in the *NPRM* do not, by themselves, protect GPS receivers that are likely to be operated in close proximity to multiple MSS METs terminals. Continuity is an operational requirement for a broad range of commercial and public safety users of GPS. In the absence of suitable arrangements for co-location operations (such as the ones under development between GPS and 1-3 GHz MSS operators), close proximity interference to GPS receivers at any of the levels proposed in the *NPRM* would end the continuous availability of GPS.

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[30] The Commission's NPRM repeats the contention of one satellite operator that, before imposing additional restrictions on MSS terminals to protect GPS, the Commission should require manufacturers and users of GNSS receivers to minimize their susceptibility to interference. *See* FCC 99-37, slip op. at 31 (¶ 75). This assertion relies on the mistaken impression that the susceptibility of GPS receivers to out-of-band noise is a function of the receiver design. Rather, the susceptibility is unrelated to the receiver design, and is strictly a function of the low level of the satellite signal.

1. As Millions Of GPS Receivers Are In Current Operation Today, A Commission Decision To Grandfather MSS Terminals At OOBE Levels Higher Than –70 dBW/MHz For Up To Six Years Would Be An Arbitrary Determination That Would Destroy GPS As A Public Utility.

The Commission proposes to grandfather terminals already operating in conjunction with GMPCS systems that have not yet obtained the current voluntary interim equipment certification by exempting them from such certification requirements because of the difficulty of recalling and retrofitting equipment already in commercial use.[31] As shown above, the proposed final OOBE levels, by themselves, do not protect GPS receivers. Any MSS METs operating at levels <u>higher</u> than –70 dBW/MHz would clearly cause substantial interference to GPS receivers. See Attachment 1.

The Commission's overarching public interest objective in this proceeding should be to protect all GPS receivers from interfering out-of-band emissions; it must not jeopardize the GPS system in an attempt to ameliorate difficulties that certain early Big LEO MSS terminal makers may face in bringing their terminals into compliance with emission limits that the Commission eventually adopts. There are millions of GPS receivers in use today in dozens of safety-of-life applications. Unquestionably, it is more important to protect the millions of users that rely on GPS for safety-of-life applications than temporarily to grandfather terminals not yet in use that will soon have to be retrofitted or replaced. Indeed, given the existence of the

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[31] *See id.* at 11 (¶ 24).

GMPCS MOU and ITU-R Recommendation M.1343, the Council cannot fathom why an interim standard for Big LEO MSS METs would even remotely be seen as desirable by anyone.

Based on the latest data, there are over 8 million direct users of GPS around the world today. The number of indirect beneficiaries of the continued reliable operation of GPS — from airline passengers to stock market investors to users of resources that are produced more efficiently as a result of GPS technology — is well into the hundreds of millions. Much of the use of GPS includes safety-of-life applications. In aviation, GPS is used for transoceanic and en route navigation, aids to landing, and for wind shear detection. In maritime environments, GPS is used for navigation on the high seas, search and rescue, positioning of buoys and marine navigation aids, docking of high-speed ferries, and precision coastal and harbor approach operations. In the differential beacon augmentation systems, GPS is used for increased accuracy in the coastal confluence zones of many nations around the world, and in surface transportation, GPS is used in such critical applications as monitoring of bridge status and train control, collision avoidance, and the transportation of hazardous materials. Also, GPS is an enabling technology for the nation's emerging Intelligent Transportation Systems ("ITS") infrastructure. Federal, state, and local governments are increasingly relying on GPS for use in ambulance, police and fire department dispatch, and to provide disaster management and relief for hurricanes, floods, earthquakes, and fires.

Any and all of these uses would be vulnerable in varying degrees to devastation from the operation of METs at the proposed interim OOBE levels. There is no rational basis for the adoption of any standard – interim or otherwise – that would cause irremediable interference to GPS receivers.

2. The GMPCS-Related Recommendation In The ITU-R Does Not Provide For Grandfathering Of Non-Compliant MSS Terminals.

The GMPCS-related recommendation in the ITU-R (Recommendation ITU-R M.1343) makes no provision whatsoever for grandfathering of non-compliant MSS terminals. Moreover, this recommendation specifies an OOBE level of –70 dBW/MHz by default for the band 1580.42 – 1605 MHz.[32] Permitting the operation of MSS METs at levels in excess of –70 dBW/MHz in the 1559-1605 MHz band, in addition to its severe impact on GPS, would contravene the relevant ITU-R recommendation for such terminals and preclude GMPCS reliance. The Commission must not let this occur.

D. Although The –70 dBW/MHz OOBE Level Can Be Accepted For 1-3 GHz MSS Mobile Earth Terminals Due To Complementarities Between The RNSS And The 1-3 GHz MSS Services, -70 dBW/MHz Cannot Become A Default OOBE Standard For The 1559-1605 MHz Band.

1. The Council Believes That The –70 dBW/MHz Limit Is Acceptable For MSS Terminals Operating In The 1-3 GHz MSS Bands Because RNSS And MSS Operators, As Well As Their Corresponding Ground Equipment Manufacturers, Plan To Work Together To Ensure That RNSS And MSS Systems Operate In A Complementary And Compatible Fashion.

Although an out-of-band emission limitation of the –70 dBW/MHz would not protect RNSS receivers operating at 1559-1605 MHz in many of the applications (safety of life

[32] *See* Recommendation ITU-R M.1343, Essential Technical Requirements of Mobile Earth Stations For Global Non-Geostationary Mobile-Satellite Service Systems In The Bands 1-3 GHz, Annex I (Table I) (1997).

and otherwise) for which they are used, the Council recognizes that there is a complementary relationship between the RNSS and 1-3 GHz MSS that provides MSS operators with the necessary incentives to ensure that their associated earth terminals are operated in a way that protects RNSS receivers from harmful interference.[33] As a result, in the ITU-R study group activities earlier this year, the Council and the United States were prepared to accept the –70 dBW/MHz limitation on out-of-band emission levels produced by 1-3 GHz band MSS METs, provided that it was made clear that this value would not be applied to any emitters other than 1-3 GHz MSS METs without independent studies.[34]

The Commission, on the other hand, appears to believe that its proposed emission limits in the *NPRM* could become the default limits for broad applications (even for other MSS mobile Earth terminals in bands operating outside the 1-3 GHz range). This is absolutely not the case, and the Council strongly opposes any suggestion that –70 dBW/MHz can be applied to any service <u>other than</u> MSS METs at 1-3 GHz.

The Commission's *NPRM* does not correlate well with the fact that the –70 dBW/MHz level was arrived at in negotiations that took several years and focused on a specific interference scenario. The Commission' *NPRM* also does not reflect the fact that the need to operate GPS and MSS in a complementary fashion places an incentive on all MSS operators, and

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[33] Specifically, as noted in Document 8D/210, MSS systems use RNSS (in particular, the U.S. RNSS system known as the Global Positioning System or GPS) for position determination, timing, and other system functions.

[34] This position is fully reflected in various U.S. contributions to the ITU-R, and in outputs from the relevant working party. *See* ITU Document 8D/210 (4 March 1999), a contribution of the United States to ITU-R Working Party 8D. *See also* ITU-R Document 8D/TEMP/142 (Rev. 2).

even their corresponding ground equipment manufacturers, to work in such a way to avoid harmful interference to the GPS. These are unique and defining conditions that absolutely preclude any generalization of the –70 dBW/MHz level into a GPS protection criterion.

2. Out-Of-Band Emission Limitations Covering The Bands 1559-1605 MHz Must Be Established For All Other Transmission Sources Through Independent Studies On A Case-By-Case Basis.

Earlier this year, the U.S. adopted an ITU position that proposed the establishment of a wideband OOBE level of –70 dBW/MHz in the band 1559-1605 MHz from 1626.5-1660 MHz METs. In so doing, the United States made it very clear that the –70 dBW/MHz limitation was not to be applied to any emitters other than MSS mobile earth terminals associated with MSS systems in the 1-3 GHz range unless and until studies have been successfully completed that address critical subjects including the particular operational characteristics of the new environment, interservice and intraservice aggregate interference levels, the impact of harmonic emissions, separation distances, and shielding.[35] In this light, it would be an anathema for the Commission to adopt as general limits OOBE levels that were developed for a specific operational scenario. Instead, it should be clear that OOBE levels for particular emitters must be established on a case-by-case basis. The only possible exception to this requirement should be if a "default" level were to be set sufficiently low such that OOBE interference from a co-located class of emitters would not rise to the level of harmful interference.[36]

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[35] *See* ITU-R Document 8D/210, at 2. This position was reflected in output materials (including a preliminary draft new recommendation on technical characteristics for MSS mobile earth terminals that would operate in the band 1626.5-1660.5 MHz) from the April 1999 meeting of Working Party 8D.

In one sense, the type of case-by-case evaluation the Council is advocating here is already reflected in the *NPRM.* The Commission notes that NTIA's recommendations for OOBE limits on MSS METs do not cover the METs of the so-called "Little LEO" service that would operate in bands below 500 MHz (principally at around 150 MHz).[37] It tentatively concluded, based on independent assessment, that the Little LEO band is sufficiently separated from 1559-1660 MHz to ensure that the low power Little LEO emissions will not interfere with RNSS reception.[38] The Commission went on to observe that the emission standards (including OOBE) for Little LEO systems are currently being considered in the ITU-R, and stated that it would consider domestic implementation in a future Commission proceeding of any ITU-R recommendation for regulations that would further restrict OOBE from Little LEO METs. In other words, the appropriate OOBE level for Little LEO MET emissions into the 1559-1605 MHz band will be set through independent evaluation. The Commission made clear, however, that the level will not be permitted to exceed –70 dBW/MHz.[39]

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36 A proposal for a threshold OOBE level that would permit operation of emitters without the need for independent studies is presented in Section III.E below.

37 *See NPRM*, FCC 99-37, slip op. at 36 (¶ 93).

38 *Id.*

39 *Id.*

E. Inasmuch As An OOBE Limit Of –100 dBW/MHz Would Protect A GPS Receiver From A Co-Located Emitter, –100 dBW/MHz Could Be Adopted As A Default Out-Of-Band Emissions Threshold For The 1559-1605 MHz Band, In Lieu Of Or Pending Confirmation Of A Higher Acceptable Level.

1. An Emissions Standard That Takes Into Account The Collocation Of METs With GPS Receivers Is Essential To Protect A Safety-Of-Life Service, Such As The GPS.

As stated above, the Commission is relying in its *NPRM* on limits that have been developed for a particular operational scenario. If, as it must, the Commission is to adopt emissions standards that protect GPS, it needs not only to require the successful completion of studies that address the pertinent technical and operational characteristics of the scenarios for which it proposes emissions standards, it must also insist upon studies that evaluate emitters that are effectively co-located with GPS receivers.[40]

A co-location standard is necessary for evaluating the impact on GPS. As noted above, GPS receivers are used in myriad applications – either as independent devices, or integrated into other equipment – where they are routinely or can be expected to be very close to an emitter of radiofrequency radiation. Certainly, a GPS receiver used in a vehicle or on a boat can be expected to be within one meter of an emitter. The same is true for practically every other type of GPS receiver. The ubiquity of GPS receivers and the broad variety of GPS applications dictates that co-location must be the condition upon which the impact of an emitter on GPS is considered.

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[40] For purposes of this proposed requirement, an emitter would be considered to be co-located with GPS if its radiation source is within 1 meter of the GPS receiver.

2. An OOBE Level Of –100 dBW/MHz Should Be Sufficient To Protect GSP Receivers Even From Interference Caused By Co-Located MET Transmitters.

Due to the inherent nature of the safety-related uses of GPS, and the constraints imposed by the GPS system specification,[41] the frequency bands used by GPS must be fully protected against interference from external sources.[42] Contrary to the incomplete expression provided in the *NPRM*, however, this protection requirement extends to all of the safety applications of GPS, be they marine or land, and not just to aviation-safety applications associated with GNSS.

The Council recognizes that there will be instances where particular emitters or classes or emitters will be claimed not to interfere with GPS, but that the operators or proponents of the technology will be reluctant to invest the resources needed to identify the appropriate OOBE level for the 1559-1605 MHz band. In this situation, it would be beneficial for the Commission to establish an OOBE "threshold" for the 1559-1605 MHz band. Thus, for those who desire to show that operation of their emitters does not interfere with GPS, even when co-located with GPS receivers, they can conduct the tests and generate the data to substantiate their claims. For others, all they have to show is that operation of their devices does not produce OOBE into the 1559-1605 MHz band at levels in excess of a default threshold that is set law

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[41] The GPS system Specification has been in the public domain since at least 1984.

[42] The importance of GPS and the need to ensure its protection is reflected in legislation as well as in the policy initiatives of the Executive Branch. *See, e.g.*, Presidential Decision Directive (1996); Defense Authorization Act (1997); Defense Appropriations Act (1998); Commercial Space Act (1998); Bilateral Agreement between the United States of America and Japan (1998).

enough not to cause harmful interference to co-located GPS receivers. This should be particularly appealing to relatively low power devices that would operate at frequencies far removed in spectrum from the 1559-1605 MHz band.

Based on the test results reported in Section III.B above, the Council suggests that the appropriate threshold default OOBE level in the 1559-1605 MHz band for co-located emitters is –100 dBW/MHz. See Attachment 1. Again, the Council wishes to reiterate that this is a conservative, default value, and it in no way precludes the establishment of OOBE levels that may be as high as –70 dBW/MHz in cases where specific, credible studies have been conducted considering all the relevant factors, including, as stated above, the particular operational characteristics, interservice and intraservice aggregate interference levels, and the impact of harmonic emissions, separation distances, and shielding.

IV. CONCLUSION

For all of the reasons stated above, the Commission must reject all of the out-of-band emission limits that have been recommended by NTIA, other than the "final" limits that would apply to MSS METs in the 1610-1626.5 MHz band. The pre-2002 and interim Big LEO limits would devastate GPS and are completely lacking in rational basis or justification.

The –70 dBW/MHz OOBE level is clearly not a protection criterion for GPS, and test data supplied by the Council confirms this. As a result, the Commission must clearly state that the –70 dBW/MHz OOBE level for 1-3 GHz MSS METs, which is acceptable to GPS (despite its unsuitability as a co-location standard) because of the complementaries between GPS and 1-3 GHz MSS and the mutual incentives created thereby, cannot be extended to any other service without independent study and verification of suitability. To the extent that it may be desirable for the Commission to adopt a "default" OOBE threshold level at which emitters other than 1-3 GHz MSS METs would be able to operate without undergoing independent study, the threshold needs to be based on a co-location standard (*i.e.*, the noise source would be one meter or less from the GPS receiver) due to the ubiquity of GPS use. Under this circumstance, the Council's data reveal that the appropriate level for this OOBE threshold in the 1559-1605 MHz band is –100 dBW/MHz.

With these essential qualifications, the Commission can both satisfy its obligation to ensure the protection of all uses of GPS, and further its policy objective of facilitating the establishment of a successful and competitive 1-3 GHz MSS industry.

Respectfully submitted,

THE U.S. GPS INDUSTRY COUNCIL

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ATTACHMENT 1

Measurement of GPS Receiver Susceptibility to Interference from a Broadband White Noise Test Source

Background

The frequency bands 1610-1660.5 MHz are allocated by the ITU for use by the Mobile Satellite Service (MSS) in the Earth-to-space direction. GPS receivers operate in a portion of the Global Navigation Satellite Service (GNSS) band that is allocated by the ITU for use by Radio Navigation Satellite Services (RNSS) from 1559 to 1610 MHz.

System operators providing equipment for use i with the MSS have sought international agreement on out of band emissions that can spill over into the GNSS band from the mobile earth terminals (METs) of MSS systems operating in either the 1610-1626.5 MHz band (which is used by non-geostationary MSS systems such as Iridium and Globalstar) or the 1626.5-1660.5 MHz band (which is used by geostationary MSS systems such as AMSC/TMI and Inmarsat).

An ITU recommendation (Recommendation ITU-R M.1343) was adopted in 1997, and, among other things, specifies maximum out-of-band emission (OOBE) levels of –70 dBW/MHz in the 1559-1605 MHz band for METs operating with non-geostationary MSS systems in the 1610-1626.5 MHz band and the 2 GHz band. A similar recommendation that remains under ITU development for METs that would operate with geostationary MSS systems in the 1626.5-1660.5 MHz band and 2 GHz band would specify similar maximum OOBE levels in the 1559-1605 MHz band.

This –70 dBW/MHz OOBE level was deemed acceptable for /GPS users in a specific aviation landing scenario This number disenfranchises the vast majority of current GPS users, including general aviation, terrestrial and marine.

Goal

The goal of this simple operational test was to determine the susceptibility of a variety of GPS receivers to the effects of interference from a broadband white noise test source radiating from a near-isotropic antenna with an Effective Isotropic Radiated Power (EIRP) of –70 dBW/MHz, -85 dBW/MHz, and –100 dBW/MHz in an area with an open view of the sky and of most GPS satellites. The goal is to establish an interference limit that would recover the potential disenfranchizement of the majority of current GPS users.
The tests were conducted to address the following questions:

At what distance from the noise source does a GPS receiver first experience a potential impairment to its position solution in the loss of the first satellite? (First satellite lost.)

At what distance from the noise source does a GPS receiver reacquire the last satellite? (Reacquisition of satellites.)

These two questions are important because, in most urban situations, many of the GPS satellites are blocked from view. The user must rely on those satellites that can be seen from his location. In these cases a user is often operating with the minimum number of GPS satellites necessary for a positioning solution. Thus, the loss of the first satellite is the crucial criterion for loss of GPS solution. The reacquisition of the last GPS satellite is necessary for resumption of GPS-based operations.

Test Method

The tests were performed at different times over a period of several months, during the daytime, with an open view of the sky. Not attempt was made to capture worse case satellite geometries. This is a test of expected operation as opposed to a test of the worst case.

Test Source

The test source consisted of a noise diode with output in the range from 1-2 GHz and powered by batteries, all mounted in a metal enclosure. An LED indicates sufficient battery power to properly drive the noise diode.. The LED will not light if the battery voltage is insufficient to power the noise source at the –70 dBW/MHz output level. The output power was calibrated against a power meter to obtain the –70 dBW/MHz level at 1575.42 MHz.

A quarter-wave vertical whip antenna with 3-element simulated ground plane was connected directly to the calibrated noise diode output. The gain of the antenna has been measured to be slightly less than 1 dB over isotropic.

Test Setup

Three setups were used:

1. Antennas were placed on the ground in a straight line. The broadband white noise test source was placed on a cart that was pushed along a line perpendicular to the antenna line.

2. Antennas were placed on the trunk of a vehicle that was equipped with an installed GPS receiver. The broadband white noise test source was placed on a cart that was pushed along a line while approaching the rear of the vehicle.

3. Antennas were placed on the back of the vehicle, and measured radially from the test source on a cart at the point of closest approach, 1 m horizontal.

Test Setup No. 1

In the first setup, the receiver antennas and the receivers were placed on the ground in a line adjacent to one another. The noise source was mounted on a cart and moved along a line perpendicular to the short array of GPS receivers and antennas, in 1 meter increments, starting from a distance of 30 meters. See Figure 1 for a layout of this test setup. The number of satellites being tracked was observed and it was noted at what distance the first satellite was lost for each receiver. The time and date of the observations were recorded. Five receivers were tested in this setup, on three separate dates. The time and date of the observations were recorded. The exact procedure for this test follows next, along with a sample of the tabular data.

The test set antenna was 83 cm above the ground.

Test Setup No. 2

In the second test setup, the antennas were all mounted on the rear trunk lid of the automobile, approximately 3 feet above the ground. One of the receivers was part of an in-vehicle navigation system, and its antenna was located on the rear deck space behind the back seat of the vehicle, about 6 inches from the bottom of the rear window. The noise source was again mounted on a cart and moved toward the array of antennas on the rear deck of the vehicle, approaching the vehicle from the rear in 3 foot increments (no meter tape was available that day.) Various views of this test setup are shown in two photographs in Figures 2-3.

Test Setup No. 3

In the third setup, the EIRP was reduced to –100 dBW/MHz. Since the effects of this level of interference occur at a much shorter distance, the radial distance from the test source to each of the receiver antennas was also noted, but only at the point of closest approach horizontally.

The time of measurement, and the event was recorded for each receiver in each measurement event. The distance at which the loss of the first satellite, loss of ability to obtain a position fix, and the recovery of all satellites originally tracked, was noted.

Test Procedure for Single Test Source

The following test procedure was used.

1. Test Source off, record number of satellites tracked being tracked on each receiver.
2. Test Source on at distance of 30 meters, record number of satellites being tracked on each receiver.
3. Decrease Test Source-to-GPS antennas range by 1 meter per 1-2 minutes down to range of 1 meter, record number of satellites being tracked on each receiver.
4. Test Source off, allow all receivers to re-acquire and go into tracking mode, record number of satellites being tracked on each receiver.
5. Increase Test Source -to-GPS antennas range by 1 meter per 2 minute period up to range of 20 meters, record number of satellites being tracked on each receiver every 2 minutes.
6. Test Source off, record number of satellites being tracked on each receiver.

The data for the tests is given in Tables II – VI. A summary of the important events is given in Test Summary A, with the associated dat extracted from the original test data.

Test Procedure for Two Test Sources

Two test sources were used to assess the inteference effects on the five receivers. The test sources were each set to –85 dBW/MHz, and measurements were made at 4 m and 3 m separation distances. Each test source was located in approximately the same place, on the cart. That test data is summarized in Test Summary B.

Receivers Tested

A total of 5 receivers underwent all the tests. The receivers were manufactured by 3 different vendors. The identity of the receivers and the vendors is suppressed. The category of receivers is shown in Table I. The receivers have been arbitrarily numbered from A thru E.

Table I: Receiver Types

Receiver	Type
A	Wide Bandwidth (cm accuracy)
B	WAAS/LAAS Reference
C	Consumer
D	General Avionics
E	In-Vehicle Navigation

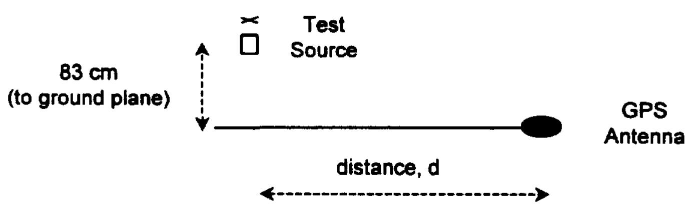


Figure 1. Side view of the First Test

Figure 2. View of Test Source Approaching Rear of Vehicle in Second Test Setup.

Figure 3. Side View of the Second Test Setup on 5.21.99

Table II: Number of Satellites Tracked vs. Distance From Test Source

Test Source Moved Towards the GPS Receivers

		Test Source EIRP:		- 70 dBW/MHz			
Receiver	A	B	C			D	E
Date	4.14.99	4.03.99	4.14.99			5.21.99	5.21.99
Distance, m				Distance, ft	Distance, m		
30		8		90	27.4	6	>3
29		8		87	26.5	6	>3
28		8		84	25.6	6	>3
27		8		81	24.7	8	>3
26		8		78	23.8	8	>3
25		8		75	22.9	8	>3
24		8		72	22.0	8	>3
23		8		69	21.0	7	>3
22		8		66	20.1	7	>3
21		8		63	19.2	8	>3
20		7		60	18.3	8	>3
19		7		57	17.4	8	>3
18		7		54	16.5	8	>3
17		7		51	15.5	7	>3
16		7		48	14.6	6	>3
15		7		45	13.7	2	>3
14	8	7	8	42	12.8	2	>3
13	8	7	8	39	11.9	1	>3
12	7	7	8	36	11.0	0	3
11	7	7	8	33	10.1	0	3
10	6	7	8	30	9.1	0	3
9	4	7	8	27	8.2	0	3
8	3	6	8	24	7.3	0	>3
7	3	5	8	21	6.4	0	>3
6	3	4	7	18	5.5	0	>3
5	1	3	3	15	4.6	0	2
4	0	0	1	12	3.7	0	1 or 3
3	0	0	0	9	2.7	0	1
2	0	N/A	0	6	1.8	0	0
1	0	N/A	0	3	0.9	0	0
0	N/A	N/A	N/A	0	0.0	0	0

Table III: Number of Satellites Tracked vs. Distance from Test Source

	Test Source EIRP = -85 dBW/MHz					6.17.99
	Test Source Moved Towards GPS Receivers					
Receiver	A	B	C	D	E	
Distance, m						Condition
6	8	8	9	8	>3	Source Off
6	8	8	8	8	>3	Source On
5	8	8	8	6	>3	Source On
4	6	8	7	5	>3	Source On
3	5	0	4	5	>3	Source On
2	3	0	4	1	2	Source On
1	0	0	1	0	1, 2	Source On
Radial Distance, cm*	118	141	133	124	150	

This is the distance between the Test Source antenna and the GPS receiver antenna as measured directly. The 1 m distance in the reference is the horizontal distance to the center of the assembly of antennas on the trunk of the vehicle.

Table IV: Number of Satellites Tracked vs. Distance from Test Source

	Test Source EIRP = -85 dBW/MHz					
	Test Source Moved Away from GPS Receivers					6.17.99
Receiver	A	B	C	D	E	Condition
Distance, m						
1	8	7	8	8	>3	Source Off
1	0	0	1	0	2,3	Source On
2	0	0	3	0	3	Source On
3	4	0	5	2	>3	Source On
4	5	4	6	3	>3	Source On
5	6	6	7	4	>3	Source On
6	6	6	7	6	>3	Source On
7	6	6	7	6	>3	Source On
8	6	6	7	7	>3	Source On
9	6	6	7	7	>3	Source On
10	6	6	7	7	>3	Source On

Table V: Number of Satellites Tracked vs. Distance from Test Source

	Test Source EIRP = -100 dBW/MHz					6.17.99
	Test Source Moved Towards GPS Receivers					
Receiver	A	B	C	D	E	
Distance, m						Condition
6	8	6	9	9	>3	Source Off
6	8	6	9	9	>3	Source On
5	8	6	11	7	>3	Source On
4	8	6	11	8	>3	Source On
3	8	6	11	8	>3	Source On
2	8	7	11	8	>3	Source On
1	6	7	11	4	>3	Source On
Closest	5	8	10	4	>3	Source On
Closest	9	8	11	8	>3	Source Off

Table VI: Number of Satellites Tracked vs. Distance from Test Source

	Test Source EIRP = -100 dBW/MHz					6.17.99
	Test Source Moved Away from Receivers					
Receiver	A	B	C	D	E	
Distance, m						Condition
1	7	8	9	7	>3	Source On
2	8	8	10	6	>3	Source On
3	8	8	10	8	>3	Source On
3	8	8	10	8	>3	Source Off

Test Summary A

Table VII: Loss of First Satellite Distance for Family of Test Source EIRP's

Distance in Meters

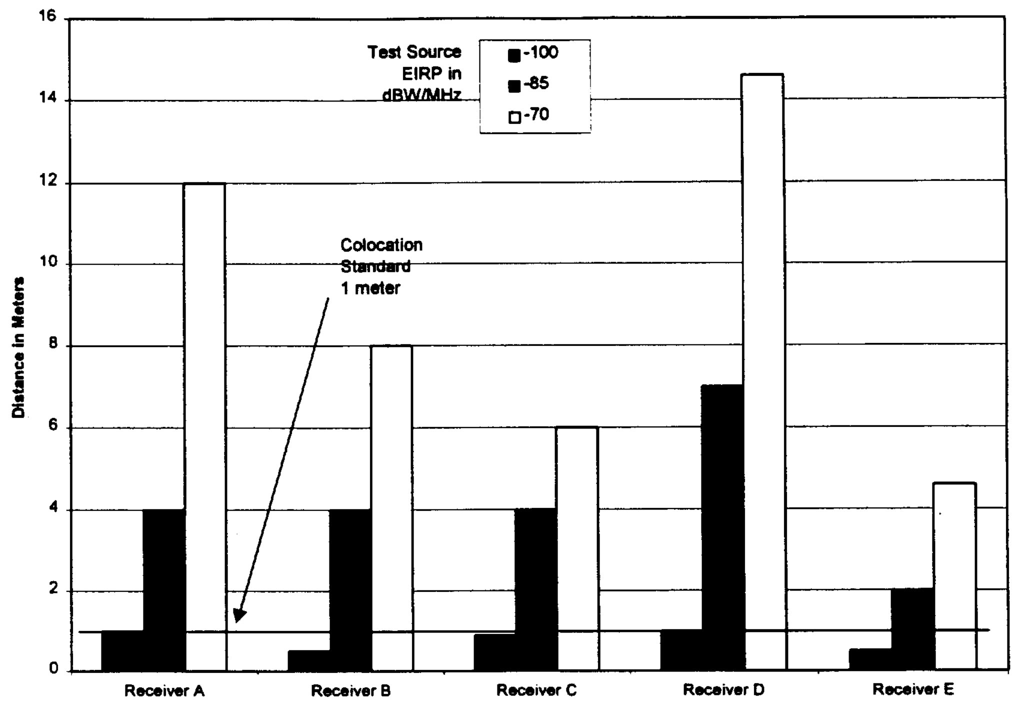
Receiver Type	EIRP in dBW/MHz	-100	-85	-70
Survey	Receiver A	1	4	12
WAAS	Receiver B	0.5	4	8
Consumer	Receiver C	0.9	4	6
General Aviation	Receiver D	1	7	14.6
In Car Navigation	Receiver E	0.5	2	4.6

All Satellites Reacquired Distance for Family of Test Source EIRP's

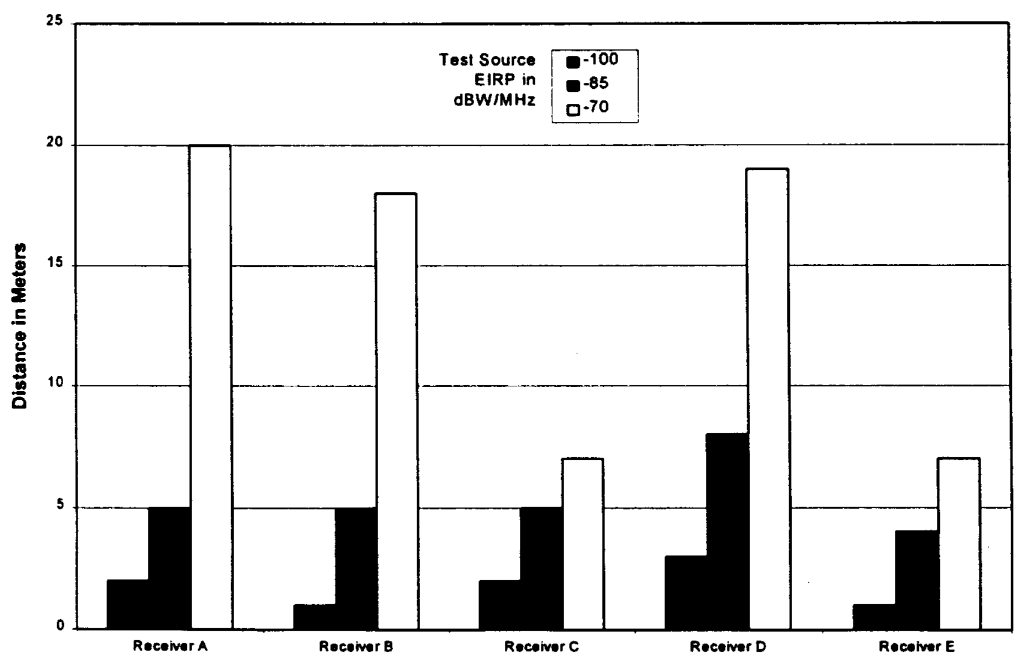
Distance in Meters

EIRP in dBW/MHz	-100	-85	-70
Receiver A	2	5	20
Receiver B	1	5	18
Receiver C	2	5	7
Receiver D	3	8	19
Receiver E	1	4	7

Loss of First Satellite Distance for Family of Test Source EIRP's



All Satellites Reacquired Distance for Family of Test Source EIRP's



Test Summary B

Table IX: Number of Satellites Tracked with Two Test Sources

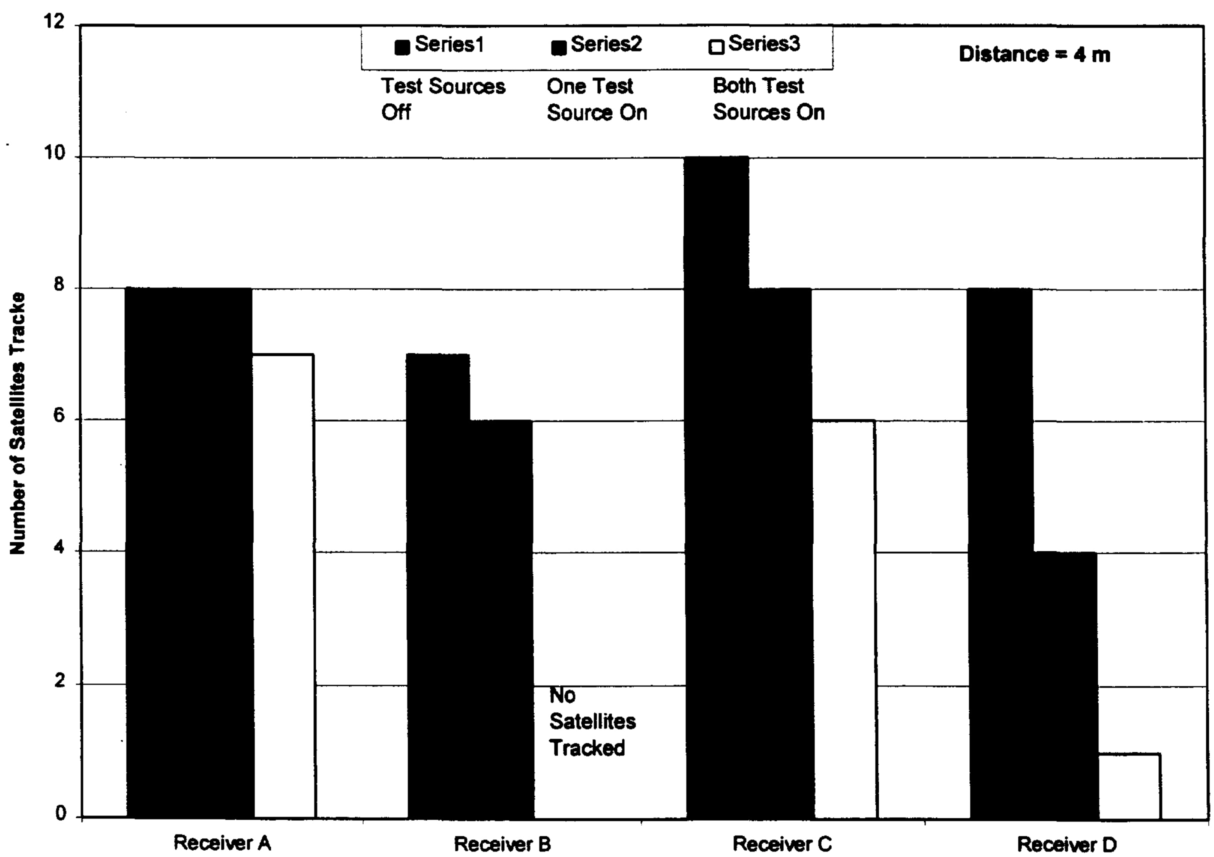
Each Test Source EIRP = - 85 dBW/MHz

Condition	Distance, m	Receiver A	Receiver B	Receiver C	Receiver D
Test Sources Off	4	8	7	10	8
TS #1 On	4	8	6	8	4
TS #1 & #2 On	4	7	0	6	1

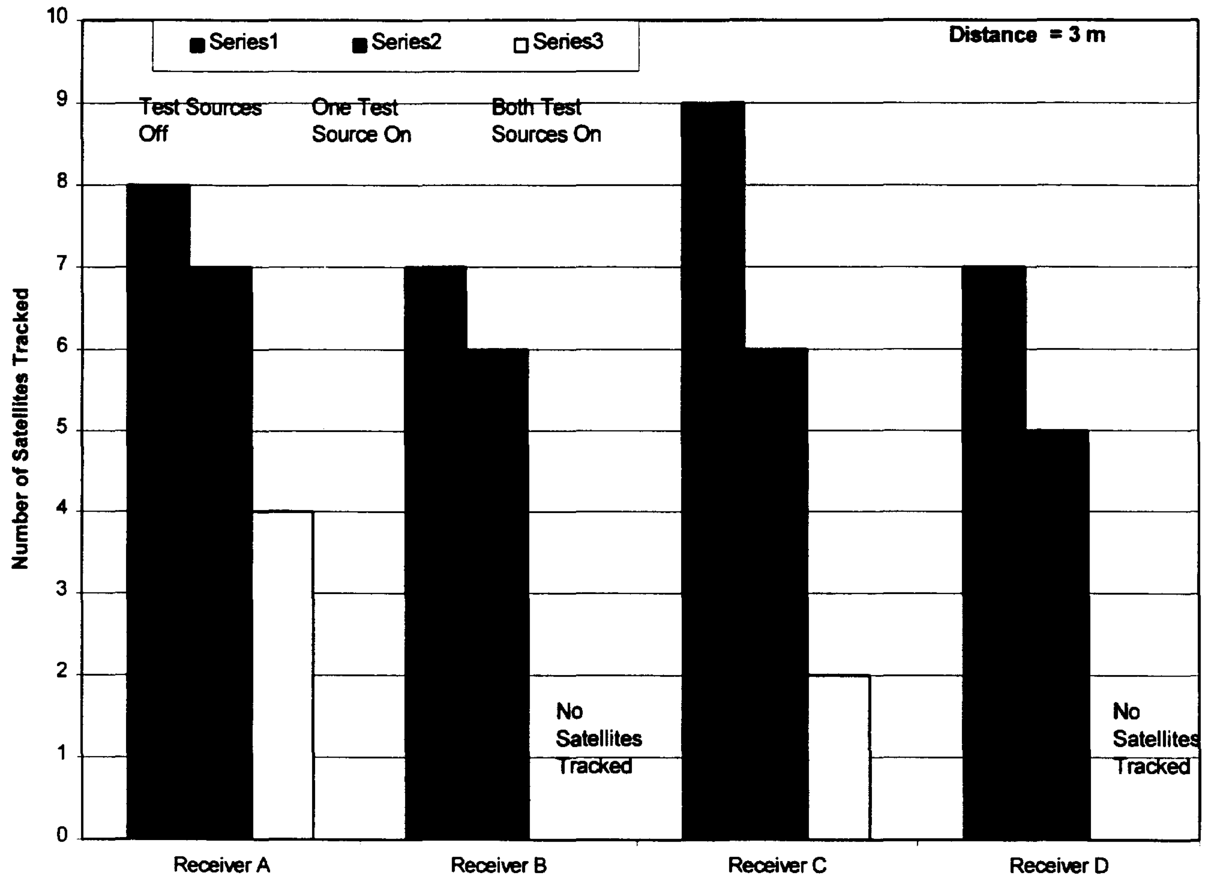
Condition	Distance, m	Receiver A	Receiver B	Receiver C	Receiver D
Test Sources Off	3	8	7	9	7
TS #1 On	3	7	6	6	5
TS #1 & #2 On	3	4	0	2	0

Receiver E exhibited no observable effects at these distances for either 1 or 2 emitters. This is consistent with the data shown in Table VII above, where tracking more than 3 satellites occurred at 2 m.

Number of Satellites Tracked for Two Test Sources



Number of Satellites Tracked for Two Test Sources



Conclusions

Current GPS Users are Affected by the –70 dBW/MHz OOBE Limit

Users of GPS (other than Commercial Aviation) are severely disadvantaged by the OOBE Limits of –70 dBW/MHz. The data substantiates this in the following way.

- The Wide bandwidth (cm accuracy) receivers are affected. In two cases, Receivers A and B experienced a loss of tracking of the first satellite at 12 meters and 8 meters of separation from the test source. Wide bandwidth receivers are representative of the type of GPS receivers being used in mining, construction, agriculture, and survey.

- The in-vehicle navigation system is affected at 4.6 meters.

- The consumer unit isaffected at 6 meters.

- The General Avionics equipment is affected at 14.6 meters.

Colocation Issue

The data taken at three different EIRPs indicates that slight damaging effects still occur at the lowest level of OOBE, -100 dBW/MHz. The other two levels, -85 dBW/MHz and the current limited applicability standard of –70 dBW/MHz, all have demonstrable effects on GPS availability at distances where GPS users are likely to encounter sources with these levels of OOBE.

Comments on Test Methodology

While the purpose of the tests were to get a sense of the effects of interference on GPS receivers, it is by no means a complete and definitive test. At first glance, the test results have occasional inconsistencies. A more refined test might consist of monitoring the number of satellites tracked over a 24-48 hour period for each separation distance, with the test source cycled on and off at a 5-10 minute duty cycle. The test would need to include varying the test source height relative to the receiver antenna height. After each test epoch, the separation distance would be decreased. The expectation is that a more complete picture of the effects of interference would be obtained. However, while these refinements in the test methodology would be expected to lead to results that are free from the apparent inconsistencies reflected in the data gathered to date, it is not expected to lead to results that are dramatically different from those reported here.

TECHNICAL CERTIFICATION

I, James M. Janky, hereby certify under penalty of perjury that I am the technically qualified person responsible for the preparation of the technical information contained in the foregoing Comments of the U.S. GPS Industry Council (including Attachment 1 hereto), and that I have either prepared or reviewed the technical information submitted in and with this pleading and found it to be complete and accurate to the best of my knowledge and belief.

By: James M. Janky

James M. Janky
Vice President, Intellectual Property
Trimble Navigation Limited

Dated: June 21, 1999

CERTIFICATE OF SERVICE

I hereby certify that I have this 19th day of July, 1999, caused true copies of the foregoing "Comments of The U.S. GPS Industry Council" to be served by hand delivery, on the following:

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Chairman
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The Honorable Susan Ness
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445-12th Street, SW
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The Honorable Harold Furchtgott-Roth
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The Honorable Michael Powell
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